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# SPECTROSCOPY OF QUASAR CANDIDATES FROM THE UNIVERSITY OF MICHIGAN LOW-DISPERSION SURVEY

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## ABSTRACT

We present the results of long-slit CCD spectroscopy on 39 objects and four close companions from the University of Michigan objective-prism survey lists. Twelve of them are quasars with redshifts ranging from 0.326 to 2.852, and an additional 12 objects (including companions) are Seyferts or active galaxies ranging in redshift from 0.0365 to 0.227. UM 443 may be a broad absorption-line quasar. UM 565 is a star with a puzzling spectrum. Spectra are presented for a total of 25 objects.

*Key words:* galaxies: redshifts–quasars–redshifts–spectroscopy

## 1. Introduction

The University of Michigan Curtis Schmidt thin-prism survey is a slitless spectroscopic survey for emission-line objects in the southern galactic hemisphere, with a limiting magnitude of about 18 (MacAlpine, Lewis, and Smith 1977*a*,*b*, hereafter UM I and UM II; MacAlpine, Lewis, and Smith 1977*c*, hereafter MacAlpine and Lewis 1978, hereafter UM IV; MacAlpine and Williams 1981, hereafter UM V; and references therein). The survey has produced 170 quasars to date, as listed in Hewitt and Burbidge (1987), including two gravitational lenses (UM 425, Meylan and Djorgovski 1989; and UM 673, Surdej *et al.* 1987), one quasar pair (PHL 1222, Meylan *et al.* 1990), and a number of Seyferts and active galaxies. Objects from the University of Michigan lists are designated UM, a convention which we follow. The information from the survey plates is rather limited, and the identification of emission features is difficult due to low dispersion, confusion with adjacent spectra, and plate flaws, necessitating follow-up slit spectroscopy to confirm the nature of the objects.

We have undertaken a follow-up slit spectroscopy program of the brighter UM objects with probable emission lines as a marginal weather backup project. Our goal is to classify the objects, obtain accurate redshifts, and identify objects worth pursuing in more detail.

*Alfred P. Sloan Foundation fellow.

## 2. Data and Results

The observations were done on UT 1988 April 7–10 and UT 1988 Setember 12 with the Modular Spectrograph on the 100-inch (2.5-m) telescope at Las Campanas, on UT 1988 July 14–16 with the 4-meter telescope at Cerro Tololo, and on UT 1988 March 10–11 with the Double Spectrograph (Oke and Gunn 1982) at the Cassegrain focus of the Palomar Observatory Hale 200-inch (5-m) telescope. The weather was generally nonphotometric with variable transparency due to cirrus clouds. The seeing ranged from 1.5 to 3 arc seconds (FWHM). The slit widths and gratings varied, but were chosen to give 3 Å to 6 Å resolution, and covered approximate ranges of 4300 Å to 7300 Å. Exposure times ranged from 400 to 2000 seconds.

Wavelength calibration was accomplished with helium, neon, argon, and hollow cathode (Fe-Ar) lamps, giving an rms error in the dispersion solutions of $\leq 1$ Å. Wavelength shifts due to instrument flexure were compensated for by taking frequent spectra of the helium arc lamps throughout the night or by checking the wavelengths of prominent sky emission lines in the 2-D spectrum of each object. We note that in some cases there was significant flexure between adjacent object spectra and the calibration lamps, so in those cases we compensated for instrument flexure by monitoring the shifts in the wavelengths of night-sky lines.

Dome flat fields and spectroscopic flux standards from

Oke and Gunn (1983), Stone (1977), Stone and Baldwin (1983), and Baldwin and Stone (1984) were used to correct for instrument response and to give an approximate flux calibration. Due to the variable transparency, the zero-point uncertainties of the flux calibration are estimated to be on the order of 0.5–1.0 magnitude. The data were reduced using standard procedures.

Thirty-nine UM objects were observed, of which 12 are quasars and eight are Seyferts or active galaxies. An additional four active galaxies were found as nearby companions to the UM objects. Six UM objects are M-type stars, while another nine were found to be early-type galactic stars. Two white dwarfs were included in the objects observed, as well as one hot galactic star of unknown type (UM 565) and two objects which could not be identified due to the absence of any discernible spectral features (UM 493 and UM 566), making them possible BL Lacertae objects. Figures 1 and 2 show the spectra of the quasars and active galxies observed, while Figure 3 shows the spectrum of UM 565.

### 3. Comments on Selected Objects

UM 189, UM 426, UM 610, UM 615, UM 630, and UM 637 are all M-type stars, the broad molecular absorption bands making the objective-prism survey spectra appear to have emission lines. UM 122, UM 432, UM 451, UM 550, UM 553, UM 599, UM 604, UM 609, and UM 640 were found to be early-type galactic stars (mostly subdwarfs) of no particular note. Either the objects were misidentified or the original detection of possible emission lines was spurious. UM 517 and UM 624 were found to be white-dwarf stars.

**UM 221 = 0012−002:** A $17^m$ quasar at $z = 1.55$. The line at λ3900 reported in UM III corresponds to C IV λ1549. There is an $18^m.5$ M-type star 10 arc sec away in P.A. = 248°.

**UM 228 = 0018+006:** A $17^m$ Seyfert II galaxy at $z = 0.0983$. The lines at λ4100 and λ3760 reported in UM III correspond to [O II] λ3727 and [Ne V] λ3426. This object was previously identified by Fairall (1978). There is another $17^m$ Seyfert II galaxy 23 arc sec to the west at P.A. = 257° which is at $z = 0.142$.

**UM 235 = 0020−018:** Possibly a $17^m$ LINER at $z = 0.065$, though with heavy obscuration. The Hβ and [O III] lines are completely absorbed. There is a companion object 9 arc sec away at P.A. = 108° which shows Na D λ5893 absorption at zero redshift.

**UM 254 = 0029−024:** A $17^m$ Seyfert II at $z = 0.0444$. The emission lines are extended over 13 arc sec at P.A. = 139°, and a velocity field of 60 km $s^{-1}$ amplitude is discernible. UM 254 is listed in the IRAS PSC (IRAS 00290-00225).

**UM 443 = 1135+007:** A $17^m$ quasar at $z = 0.804$, possibly with broad absorption lines. The Mg II line shows some continuum depression blueward of the peak; thus, the redshift is uncertain. The line at λ3580 reported in UM V corresponds to the C III] λ1909 line.

**UM 479 = 1207−000:** A $17^m$ galaxy at $z = 0.0993$, determined from Na D λ5893 and Mg I λ5689 absorption lines. The possible line at λ4560 reported in UM V apparently was a plate flaw.

**UM 493 = 1219−008:** A $17^m$ possible BL Lac, otherwise it is not identifiable from the featureless spectrum. There may be a faint absorption line at the 1σ or 2σ level from Hα at zero redshift, making UM 493 a galactic star.

**UM 553 = 1312+021:** Although the object identified in UM V as UM 553 is an $18^m$ star, there is a $19^m$ compact emission-line galaxy 8.5 arc sec away at P.A. = 270° with a redshift of $z = 0.1288$. Sixty-one arc sec away from UM 553 in P.A. = 255° is an emission-line galaxy ZwG 016.031, which lies at $z = 0.035$ (see Fig. 4). Both of these objects were observed earlier at Lick by S.D.

**UM 565 = 1317+020:** A hot star with an unusual spectrum (see Fig. 3). The Balmer series is present through Hη λ3834, where our spectrum cuts off, but the Hα and Hβ lines show splitting. There is a similar asymmetry to the other absorption lines through Hε λ3969. The difference between the two major components of the Hβ line amounts to 53 Å, or a velocity difference of 3260 km $s^{-1}$, ruling out the interpretation that this is a binary system. UM 565 is also unlikely to be a magnetic white dwarf, since the Balmer lines are quite strong and not blended together blueward of Hε.

**UM 566 = 1317+021:** An $18^m$ possible BL Lac with a flat, featureless spectrum. The signal-to-noise ratio of this spectrum is poor, so weak emission or absorption features could have been missed.

**UM 607 = 1340−006:** A $16^m$ quasar at $z = 0.326$. There is a starburst galaxy 9.4 arc sec away in P.A. = 338° at $z = 0.227$. Unpublished spectroscopy from ESO by G. Meylan confirms this result.

**UM 615 = 1348−016:** The object identified as UM 615 in UM V is an $18^m$ M-type star with strong Hα emission. However, there is a companion object 12 arc sec away in P.A. = 90° which is 2.6 magnitudes fainter and shows some weak emission lines of Hβ and [O III] at $z = 0.0826$. Because this object is nearby and faint it is most likely a dwarf galaxy undergoing a starburst phase.

**UM 653 = 1413−012:** An $18^m$ Seyfert II at $z = 0.0365$. The emission lines are extended over 11 arc sec at P.A. = 90° and a velocity field of 110 km $s^{-1}$ amplitude is discernible.

**UM 654 = 1413−011:** An $18^m$ Seyfert II at $z = 0.0369$. The emission lines are extended over 9.4 arc sec at P.A. = 90° and a velocity field of 130 km $s^{-1}$ amplitude is discernible.

**UM 658 = 2244−223:** Previously idenitfied as a quasar by MacAlpine and Feldman (1982).

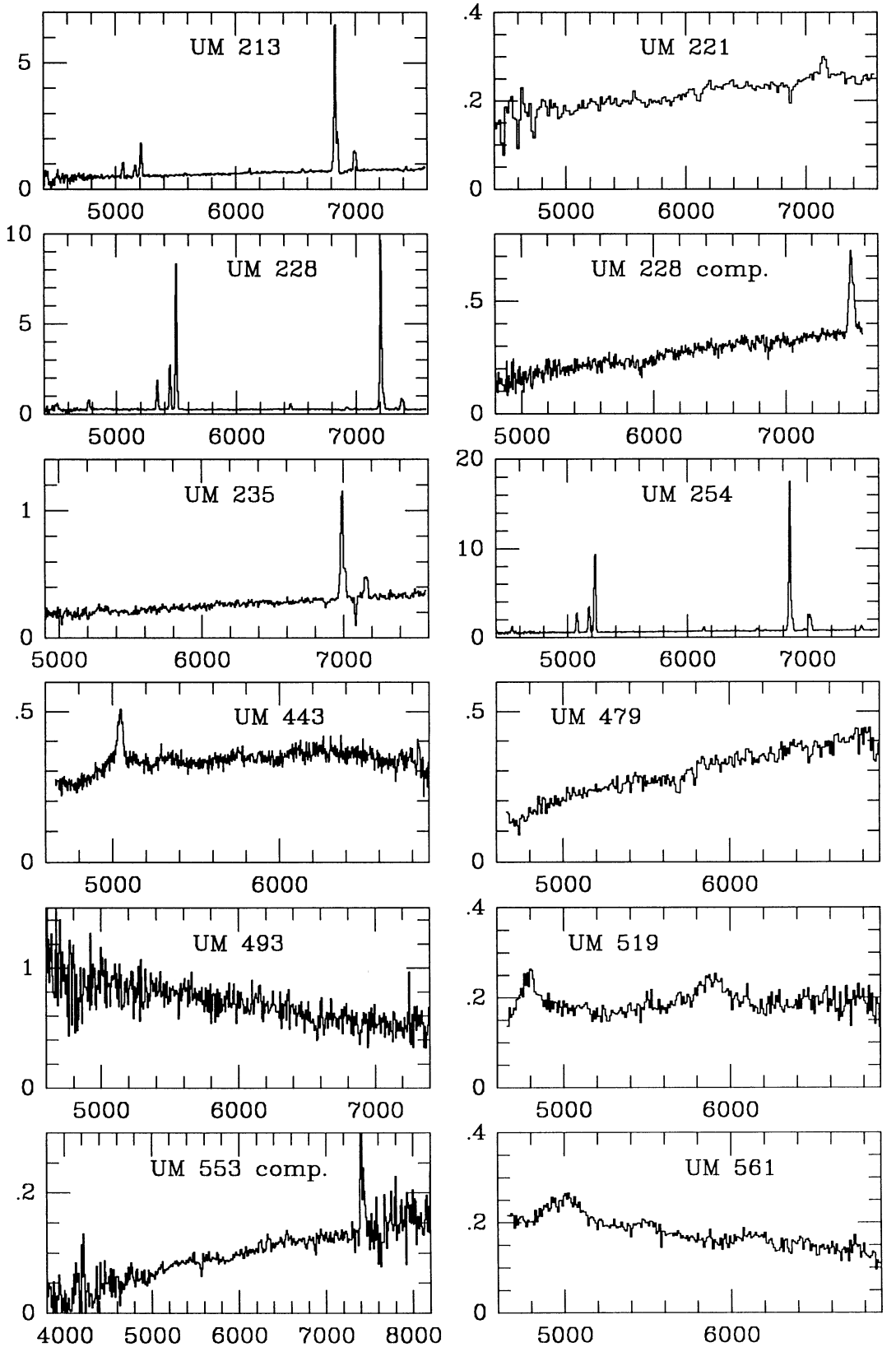


FIG. 1–Spectra of UM 213, UM 221, UM 228 and its companion, UM 235, UM 254, UM 443, UM 479, UM 493, UM 519, the companion of UM 553, and UM 561. The flux calibration zero point is uncertain by as much as 0.5–1.0 magnitude. See the text for details on selected objects. Spectra are plotted as $F_\nu$ (mJy) versus λ(Å).

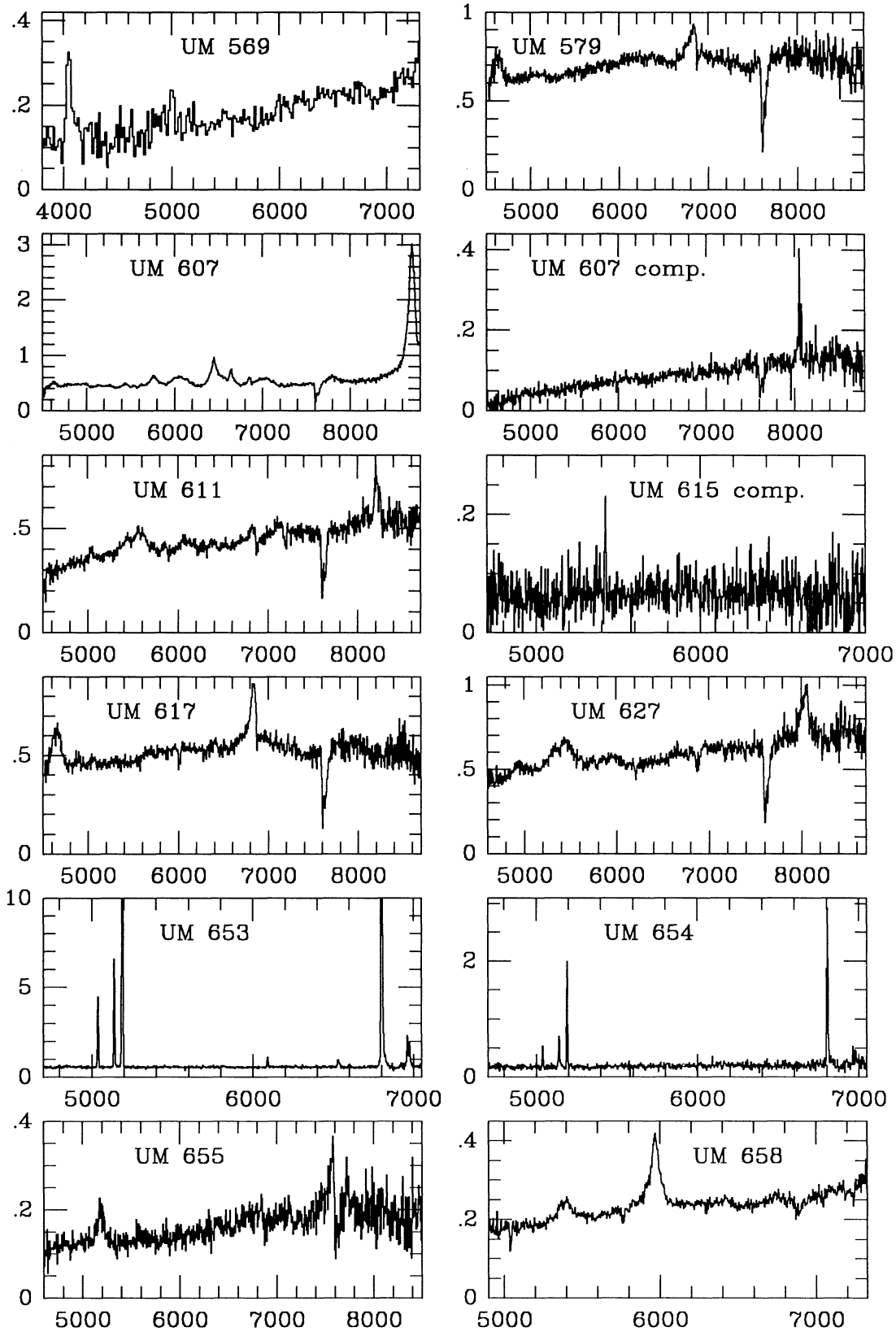


FIG. 2–As in Figure 1, but for UM 569, UM 579, UM 607 and its companion, UM 611, the companion of UM 615, UM 617, UM 627, UM 653, UM 654, UM 655, and UM 658.

Table 1

Quasars and Active Galaxies

| Source | Line | rest | obs | z | ID, average z |
|---|---|---|---|---|---|
| UM 213 | H-beta | 4861 | 5059 | 0.04087 | Starburst or LINER |
| = 0009-003 | [O III] | 4958 | 5161 | 0.04077 | z=0.0408+/-0.0003 |
| | [O III] | 5007 | 5211 | 0.04082 | |
| | H-alpha | 6563 | 6830 | 0.04070 | |
| UM 221 | Mg II | 2798 | 7140 | 1.55 | QSO |
| = 0012-002 | | | | | z=1.55+/-0.01 |
| UM 228 | H-gamma | 4340 | 4768 | 0.09838 | Seyfert II |
| = 0018+006 | H-beta | 4861 | 5339 | 0.09834 | z=0.0983 +/- 0.0003 |
| | [O III] | 4959 | 5447 | 0.09837 | |
| | [O III] | 5007 | 5499 | 0.09831 | |
| | He I | 5876 | 6452 | 0.09815 | |
| | H-alpha | 6563 | 7207 | 0.09808 | |
| UM 228 comp. | H-alpha | 6563 | 7496 | 0.142 | Seyfert II |
| | | | | | z=0.142 +/- 0.001 |
| UM 235 | H-alpha | 6563 | 6990 | 0.06505 | LINER? |
| = 0020-018 | [S II] blend | 6716 | 7154 | | z=0.065+/-0.001 |
| UM 254 | H-beta | 4861 | 5077 | 0.04431 | Seyfert II |
| = 0029-024 | [O III] | 4959 | 5179 | 0.04438 | z=0.0444+/-0.0003 |
| | [O III] | 5007 | 5230 | 0.04442 | |
| | H-alpha | 6563 | 6854 | 0.04430 | |
| UM 443 | Mg II | 2798 | 5047 | 0.804 | QSO |
| = 1135+007 | Fe II blend | 2950 | 5352 | | z=0.804+/-0.002 |
| | Fe II blend | 3200 | 5750 | | |
| UM 479 | Mg I abs. | 5178 | 5689 | 0.1015 | Galaxy |
| = 1207-008 | Na D abs. | 5893 | 6479 | 0.0993 | z=0.1005+/-0.001 |
| UM 493 | no lines | | | | Possible BL-Lac |
| = 1219-008 | | | | | |
| UM 519 | C IV | 1549 | 4803 | 2.0999 | QSO |
| = 1245-004 | C III] | 1909 | 5858 | 2.0690 | z=2.09+/-0.01 |
| UM 553 comp. | [O II] | 3727 | 4207 | 0.1288 | Starburst Galaxy |
| | H-alpha | 6563 | 7409 | 0.1288 | z=0.1288+/-0.0005 |
| UM 561 | C IV | 1549 | 4998 | 2.2258 | QSO |
| = 1315+014 | He II | 1640 | 5483 | 2.3431 | z=2.23+/-0.02 |
| | C III] | 1909 | 6109 | 2.2008 | |
| UM 566 | no lines | | | | Possible BL-Lac |
| = 1317-021 | | | | | |
| UM 569 | C IV | 1549 | 4049 | 1.613 | QSO z=1.617+/-0.004 |
| = 1319+006 | C III] | 1909 | 5003 | 1.621 | |
| UM 579 | C III] | 1909 | 4635 | 1.4283 | QSO z=1.43 +/- 0.01 |
| = 1326+021 | Mg II | 2798 | 6829 | 1.4407 | |

Table 1 (continued)

| Source | Line | rest | obs | z | ID, average z |
|---|---|---|---|---|---|
| UM 607 | H-delta | 4102 | 5439 | 0.3260 | QSO |
| = 1340-006 | H-gamma | 4344 | 5758 | 0.3265 | z=0.326+/-0.001 |
| | Fe II blend | | 6029 | | |
| | H-beta | 4861 | 6444 | 0.3256 | |
| | [O III] | 5007 | 6636 | 0.3252 | |
| | Fe II blend | | 7012 | | |
| | He I | 5876 | 7792 | 0.3261 | |
| | H-alpha | 6563 | 8708 | 0.3268 | |
| UM 607 comp. | H-beta | 4861 | 5967 | 0.2275 | Starburst galaxy |
| | H-alpha | 6563 | 8053 | 0.2271 | z=0.227+/-0.001 |
| UM 611 | C III] | 1909 | 5565 | 1.915 | QSO |
| = 1344+016 | Fe II blend | 2100 | 6075 | 1.89 | z=1.92+/-0.01 |
| | C II] | 2326 | 6817 | 1.93 | |
| | Fe? | 2300 | | | |
| | Mg II | 2798 | 8210 | 1.933 | |
| UM 615 comp. | H-beta | 4861 | 5262 | 0.0823 | Starburst or LINER |
| (= 1348-016) | [O III] | 5007 | 5422 | 0.0829 | z=0.0826+/-0.0003 |
| UM 617 | C III] | 1909 | 4662 | 1.4427 | QSO |
| = 1349+001 | Mg II | 2798 | 6828 | 1.4404 | z=1.441+/-0.002 |
| UM 627 | C III] | 1909 | 5436 | 1.8482 | QSO |
| = 1358+000 | Mg II | 2798 | 8054 | 1.8784 | z=1.865+/-0.01 |
| UM 653 | H-beta | 4861 | 5038 | 0.0364 | Seyfert II |
| = 1413-012 | [O III] | 4959 | 5139 | 0.0364 | z=0.0365+/-0.0002 |
| | [O III] | 5007 | 5189 | 0.0364 | |
| | He I | 5876 | 6090 | 0.0365 | |
| | [O I] | 6300 | 6531 | 0.0366 | |
| | H-alpha | 6563 | 6802 | 0.0365 | |
| | [S II] blend | 6716 | 6961 | | |
| UM 654 | H-beta | 4861 | 5040 | 0.0368 | Seyfert II |
| = 1413-011 | [O III] | 4959 | 5142 | 0.0369 | z=0.0369+/-0.0002 |
| | [O III] | 5007 | 5192 | 0.0369 | |
| | H-alpha | 6563 | 6804 | 0.0368 | |
| | [S II] blend | 6716 | 6963 | | |
| UM 655 | C III] | 1909 | 5177 | 1.7121 | QSO |
| = 1418+020 | Mg II | 2798 | 7574 | 1.7068 | z=1.71+/-0.01 |
| UM 658 | O+Si blend | 1401 | 5402 | | QSO |
| = 2244-223 | C IV | 1549 | 5970 | 2.8525 | z=2.852+/-0.002 |

## 4. Concluding Remarks

As with our earlier paper based on the Case Low-Dispersion Survey for emission-line objects (Thompson, Djorgovski, and Weir 1989), the University of Michigan (UM) lists provide a good yield of quasars and other interesting objects. We note, however, that the objects were chosen because of the probable presence of emission lines, as described in the original papers (UM I–V).

The most interesting objects in this sample are UM 443, which is a possible BAL QSO with fairly strong Fe lines, and the three Seyfert II galaxies UM 254, UM 653,

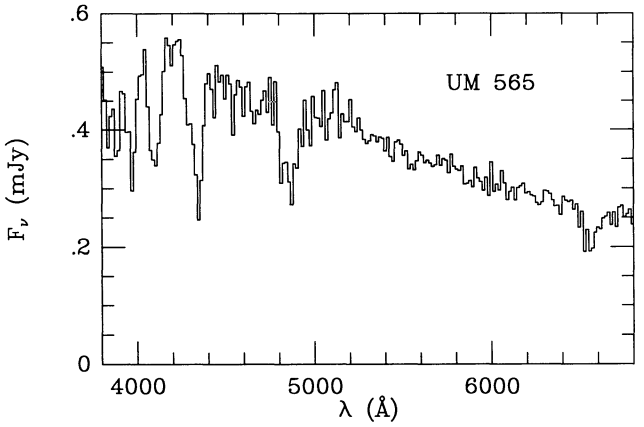


FIG. 3–The spectrum of UM 565 obtained at Palomar Observatory. Note the splitting of the Hα and Hβ absorption lines.

and UM 654, which show extended emission and significant velocity fields. Three of the quasars have $z > 2$: UM 519, UM 561, and UM 658, which may be useful in absorption-line studies, though spectra of both higher resolution and signal-to noise ratio are needed. UM 565 is a star with an interesting spectrum and is worth pursuing further.

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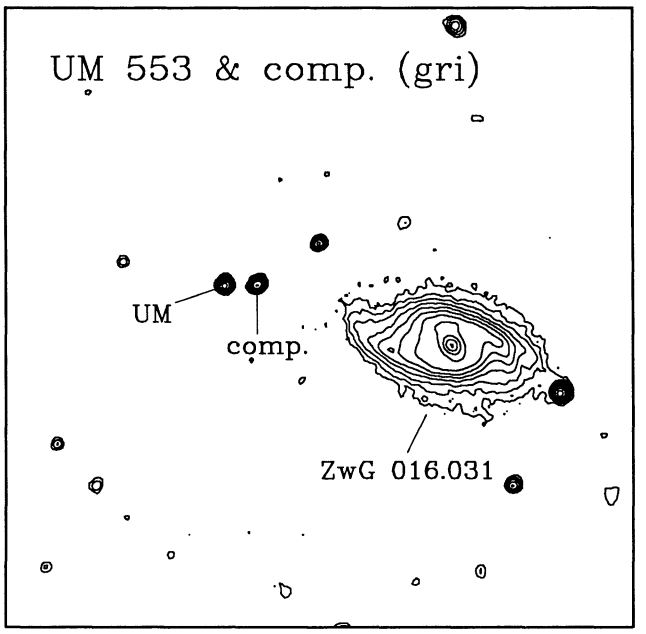


FIG. 4–A *gri* stack image (300-seconds exposure in each filter) of the UM 553 field. North is up and east is to the left in this 2.7-arc minute-square image taken on UT 1988 January 21 with the Palomar Observatory 60-inch (1.5-m) telescope.

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